Control method, device and system for robot applications

TECHNICAL FIELD.

The invention relates to a control method, device and system
for industrial robots or manipulators. In particular the
invention concerns a robot installation or application
containing at least two industrial robots, at least one of
which comprising at least four axes for servo-controlled
movements. An industrial robot in this context comprises a
manipulator with electric motors and a control means
containing power means for driving the motors and computer
means which by instructions from a computer program is
arranged for sensing and controlling the manipulator
movements.

BACKGROUND ART

Industrial robots are used to carry out a very wide range of
industrial and/or commercial tasks quickly and accurately. In
many applications, for example welding car bodies or painting
automobiles, the robot must operate a tool such as an arc
welding tip, paint sprayer or a gripper etc. to carry out pre-
programmed tasks repeatedly with consistent accuracy and
speed. Painting of car bodies on an industrial scale usually
takes place in a painting booth, through which the car bodies
are moved in succession on a conveyor in a line. Two or more
robots may be coordinated to paint the same car body in a
production section such as a paint booth. The robot
installation described above has a high degree of freedom of
movement, long reach, can access places inside hollow
sections, box sections performs well in service. The robot
installations are advantageous and more versatile when
compared to the traditional automated devices, such as simple

type of hard automation solutions as reciprocators or the
like.

However, it is a complex and demanding task to arrange and
5   program robots to carry out operations on in a common
workspace in a coordinated fashion. Much engineering and
programming effort and constant exchange of signals is
required in order to avoid collisions between robots. Such
collisions may cause damage which interrupts production and
10   may be expensive to repair. Moreover, for each new work object
that is to be processed, the lengthy engineering and
programming work must be repeated. Also a problem that may
occur with robot automation, for example in a conveyor line
situation, is that when the conveyor stops and a stoppage
15   occurs, each or every robot must be individually checked and
or manually operated or "jogged" to a known or "home"
position. This problem and collisions that may occur usually
results in either scrapped product, or unacceptable quality;
or lost production; or both.
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SUMMARY OF THE INVENTION

The invention solves one or more of the above problems.

25   According to one aspect of the invention, the object is
achieved by the initially defined method comprising checking a
value for a common reference for a robot before the start of
the next task and providing a signal to the robot to stop and
wait at the end of the present task if the value for the
30   common reference is not within acceptable limits. The method
provides for one or more of the robots to wait at the end of
the current task, and not to proceed with the subsequently
programmed task until the value for the common reference value
is acceptable. This results in that whether the one or more
35   robots wait or pause temporarily, or whether the wait

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continues for sufficient time so that all robots wait, when
one or more of the robots re-start, each of them do so in a
predetermined way by proceeding to the next task they had been
programmed to carry out.

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According to another embodiment, the method comprises steps to
check a value for a position reference for each robot before
the start of the next task and provide a signal to the robot
to stop and wait at the end of the present task if the value

10   for the position reference is not within acceptable limits.
This prevents delays or stoppages due to a work object being
moved into position later than expected. Similarly, the robot
is re-started and proceeds to start the next task as soon as
the position reference value is detected to be acceptable.

15   This embodiment provides a means to pause a robot during
execution of a movement program as well as a means to recover
from stoppage of any duration.

According to another embodiment, the method comprises steps to

20   check a value for a reference for any robot in the plurality
of robots or installation before the start of the next task
and provide a signal to a given robot to stop and wait at the
end of the present task if any other robot currently displays
a value for the position reference or other reference that is

25   not within acceptable limits. The embodiment provides a means
to pause a robot during execution of the movement program of
the robot, as well as a means to recover from stoppage by any
other robot of any duration.

30   According to another aspect of the invention, the object is
achieved by the initially defined control device comprising a
logic function such as a software or computer program member
for determining whether a value for a common reference for a
robot before the start of the next task of the robot, and a

35   logic member for making a decision if the value is acceptable

or not, and an output member to provide a signal to said robot comprising an instruction to wait.

According to another embodiment, the control device comprises a logic function implemented as a computer program for determining or detecting a value for a position reference for a work object relevant the robot before the start of the next task of the robot. If the work object is not in the expected position, the robot is instructed to wait.

According to another embodiment, the control device comprises a logic function implemented as a computer program for determining or detecting a value of a reference for at least one other robot of said plurality of robots, before the start of the next task. If any other robot has stopped, the present robot may be instructed to stop and wait.

According to another aspect of the invention, the object is achieved by the initially defined control system comprising at least one robot controller arranged capable to check a reference value for of any of said plurality of robots. The control system may instruct any robot to wait if any of: a common reference value, a work object position value are not acceptable; or, if any robot has already stopped. According to a preferred embodiment the control system also comprises a graphical user interface to display and carry out actions in respect of at least one robot controller or cell controller controlling at least one of the robots by means of the described movement program wherein the movements are executed as predefined tasks carried out in a predefined order.

A major advantage of the present invention is that robots may be programmed for cooperative or coordinated automation operations more quickly and more simply. The inventive strategy for the robot to wait at the end of a completed task

if criteria to begin the next task are not acceptable has
important consequence for programming a series of coordinated
tasks. If a stoppage occurs ahead of a task that a robot is
carrying out, the robot completes the present task but does

5   not proceed to the next task. In this way, the programmer
knows in what position the robot will be if it waits before
proceeding. The number of possibilities the programmer must
anticipate for each movement in a task is thereby greatly
reduced. The job of programming is thereby greatly simplified,

10   and may be carried out in a shorter time. After a movement
program has been produced, the time to teach it to the robots
it also reduced, because recovery after a stoppage does not
require the type of anticipation, precautions, position re-
checking and so that the methods of the prior art require.

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Another important advantage of the invention is that a
production line or conveyor may be re-started quickly
following a stoppage with a minimum or no loss of quality.
This represents a great saving in production time otherwise

20   lost due to random or unplanned stoppages in automated
production sections. At the time of a stoppage, each robot in
the affected section or production cell or production line
stops at the completion of one task and is waiting before
proceeding to a subsequent task. When the line or section is

25   re-started, each robot literally picks up where it left off,
and proceeds to start the next task. Robots do not need to be
manually jogged or automatically re-positioned before the line
can be re-started, and work objects do not need to be moved,
scrapped or replaced.

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Another advantage of the present invention is a great saving
in time and expense due to damage arising from collisions
between a robot and a work object or between two robots.
Another, further advantage is that the simplified strategy for

35   a movement program, wherein all the movements in the program

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are divided up into tasks and the controller checks that there
is no flag set high before proceeding to a subsequent task
results in a much quicker set up time and reduced
commissioning time when installing or re-configuring a line or
5   section. As much of the invention is implemented in software
the necessary time and capital cost of including the invention
in both new installations and existing installations is
relatively low and therefore very advantageous.

10   According to another aspect of the invention, the objects are
achieved by a computer program directly loadable into the
internal memory of a computer or processor, comprising
software code portions for performing the steps of the method
according to the invention, when said program is run on a
15   computer or processor. The computer program is provided either
on a computer readable medium or through a network, such as a
local area network or a wide area network including the
Internet.

20   According to still another aspect of the invention, the
objects are achieved by a computer-readable medium having at
least one program recorded thereon, where the program is to
make a computer or processor perform the steps of the method
according to the invention, when said program is run on the
25   computer or processor.

BRIEF DESCRIPTION OF THE DRAWINGS
Embodiments of the invention will now be described, by way of
30   example only, with particular reference to the accompanying
drawings in which:
FIGURE 1 is a schematic diagram of method for teaching a robot
one or more tasks according to a method of the Prior Art;
FIGURE 2 is a schematic diagram of method for teaching one or
35   more robots in a production line with several robots one or
more tasks by means of a method according to an embodiment of
the invention;

FIGURE 3 is a schematic diagram showing a work object, a
plurality of robots and a robot controller according to an
embodiment of the invention;

FIGURE 4a is a flowchart for a method for teaching a movement
5   program according to an embodiment of the invention to a
robot, and Figure 4b is an alternative flowchart showing an
option for both a verification stage and an operational flow;

FIGURE 5 is a flowchart for a method for measuring a common
reference, work object movement for example, before the
10   beginning of a new stroke;

FIGURE 6 is a flowchart for a method for checking the object
position/status continually;

FIGURE 7 is a flowchart for a method for checking the object
position/status of each other robot continually;

15   FIGURE 8 is a schematic block diagram of a robot controller
with members, parts and software for monitoring for the
reference thing position or time to control robot operation;

FIGURE 9 is a schematic block diagram of a control system for
four robots operating on a work object in a common space, a
20   production cell of a production line.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Figure 1 (Prior Art) shows a method for teaching tasks to one
or more robots according to a known method. In order to set up
25   a new or changed job, a series of 4 phases or steps are
repeated until satisfactory production results are achieved,
these being:

-design a communication concept between robots and controller,
-develop a movement program for each robot and teach it to
30   each robot,

-coordination testing, movement adjustments, repeated testing
till satisfactory,

-exception handling routines, testing recovery routines,
repeated till satisfactory,

35   -begin production.

Figure 2 summarises a method for teaching tasks to one or more
robots according to an embodiment of the invention for
controlling the one or more robots. It is immediately apparent
how much quicker pre-production changes and set-up are made by

5   use of the method. The diagram shows that use of the new
method means that the pre-production set up phase is limited
fewer phases (2) and finite repetition of only one of them.
This is to be compared to the prior art method which requires
a large number of iterations for each of two of the four

10   phases, each heavily dependent on task complexity and the
skill of the set-up user operator. The set-up phases according
to the embodiment now consist only of:
-develop a movement program 21 for each robot and teach it to
each robot,

15   -coordination testing, movement adjustments, one run for
teaching and one run for verification,
-begin production.

Figure 4a shows a flowchart for a method for teaching a

20   movement program according to an embodiment of the invention
to a robot of the plurality of robots working in a common
workspace. It shows that a program controlling the robot is
set to teach mode 41 for the present movement program. It
shows a step 43 where the robot is moved to a desired start

25   position 43 for a movement, and that start position,
coordinates for the start position, recorded and saved, which
is preferably saved automatically with position and or time
coordinates. The robot is then allowed to move to the start of
the first movement of the next task 49. This means that data

30   is stored in the system so that when the conveyor has eg moved
1001 mm and or the clock has registered eg 100.01 seconds the
work object should be in in position (within a window) to
start task n. These positions and/or times may preferably be
automatically recorded during a single verification run

35   following writing the movement program. In the verification

run-through, if a robot moves too close to another robot or to the work object etc, the technician presses a pause button on a control unit, or teach pendant etc., until the approaching object has moved away, then releases the pause button so that

5   the given robot can begin the next task. This process is repeated over and over again while the start position (and or time) for the first movement, or part movement, of each task in the movement program is being recorded and saved.

10 These start positions, the coordinates of the positions, may later be edited after a manual comparison, or an on-screen comparison of the positions and coordinates to adjust or fine-tune the start points. Instructions may also be included in the tasks of the movement program to wait for a given

15 recorded or input time period before moving to the next movement in the task, or to the next task. For example, a helper robot that opens a vehicle door for another robot to reach inside and paint the interior, may be held up by a suitable recorded or input time delay until the painting robot

20 shall have finished painting and withdrawn.

Figure 4b shows steps of a method for controlling a robot with a tool according to the preferred embodiment of the invention. The program starts at step 41b and the robot moves to the

25 first task (which may be the next task) 43b. When the robot is in a teaching (programming) mode or a verify (program) mode, step 45b is included to capture, preferably automatically, a common reference value used by all the robots such as a time or coordinate position at which the next task starts. When

30 operating in normal production mode, step 45b is by-passed. The robot moves through all the movements 40b of the present task. Before starting the next task, the robot checks 42b, a common reference value to see if the common reference value in use, a time at which a work object is in place or a position

35 of the work object in order to start (similar to 61, 71 figs

6, 7), if that value is acceptable 44b. If the common

reference value is within limits a Yes results in the robot

starting 49b the next task. If the common reference value is

not acceptable, N, 47b, the robot waits 44b (similar to 64 or

5   74 figs 6, 7) until such time as the common reference value is

found to be within limits. In this way a temporary stoppage in

a production line or cell does not result in a robot stopping

in an uncoordinated way, so that each robot must be manually

jogged to some next position or home position before a re-

10   start may be carried out. Instead, each robot simply resumes

operations at the start of the next task following the end of

the task at which they stopped.

When repeating the program the robots will execute the

15   movement as first programmed, but if the actual reference

value measured or sensed is lower than expected, the robot

will wait until it is larger or equal to the stored reference

before continuing. If the actual reference value is higher

than the stored reference value, a given robot may, depending

20   on the conditions predetermined by the movement program, send

a signal to the external reference controller/time keeper that

it is late and the conveyor will halt or the time reference

will stop until the given robot has caught up again

25   Figure 3 is a schematic diagram for a plurality of robots with

a central controller or a a controller such as a cell control

that has a superior and supervisory function. Each robot may

have a controller of its own in the usual way, subordinated to

some extent, to a more "central" controller such as a cell

30   controller. Figure 3 shows a plurality of robots 33a-n such as

Robot 3, Robot 1, Robot 2 and Robot n. One such cell

controller 31 is shown with a control communication channel

such as 35 to each robot such as Robot n. A work object 39 is

shown, and the position of the work object is reported to the

35   robots, and/or to a cell controller if the work object is a

moving object. A communication channel 37 is shown for
information relative to the work object.

The Movement Program developed according to the invention

5   usually includes a number of movements. One or more movements
are then normally handled as one or more tasks. In a painting
program, for example, each separate paint stroke (movement)
may be treated as a separate task. With spot welding, movement
to and performance of each spot weld may be a task, whereas

10 when a robot application is packing items in a box or
container, each item may be a task or each row of items packed
or each layer of items packed may be selected as one task if
that is an appropriate way to divide up the movements in the
program. In certain cases, for example, when making a

15 continuous movement such as for a robot controlled laser or
high power water jet to cut through a steel plate or similar,
a single movement that carries on for a relatively long time
or distance may be divided up into more than one task.

20 Having defined and taught or programmed a Movement Program for
a robot as including a number of movements comprising tasks,
the next principle behind the invention is that in the event
that a stoppage occurs, the robot <u>completes</u> the present task
but may <u>not</u> begin the subsequent task. The robot simply waits

25 until an instruction is received to continue before proceeding
with the next task.

Figure 9 shows a schematic block diagram of, in this exemplary
example, four robots working on a car body in a production

30 cell, with a control system for the robots indicated
symbolically. The figure shows a transport means 90 and a
section of a production line. The transport means 90 moves in
the direction of the arrow A. A work object 39, in this case a
car body, is transported by the transport means 90 into a

35 working area of, in this case, four robots, 33a-d. The robots

are controlled by a control system, and each is connected by a
suitable data network 94 which may be wired, wireless, or a
mixture of both. The transport means is powered by an
actuator, or motor 91, and movement of the transport means is
5   recorded by an encoder 92; a pulse encoder or other device for
registering the movement of a conveyor belt, rail, pallet or
other transport means. A clock 93 may also be arranged to
measure time elapsed, typically for the period(s) during which
the conveyor or other transport means is moving.
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Thus the common reference value, a reference value that all
the robots may use as a common reference value to coordinate
with each other may conveniently be provided by a sensor
member such as a pulse encoder 92 that registers movement of
15   the work object indirectly via movements of the conveyor. Such
movement registration may be accomplished using any known
sensor technique applied to a transport member
arranged to move work objects to and from the common workspace
by a conveyor or similar, or even by other transport forms
20   such as in-floor track, overhead transport, trolleys, self-
guided trolleys and the like.

Alternatively, a local time or time stamp may be provided to
each robot controller and each cell controller. If the time
25   stamp shows that the clock 93 has stopped, so as to say, then
the local time reference value has obtained a status of not
acceptable, or line stopped. When the time or time stamps
become available again, then the local time reference value is
acceptable. However, a simple movement tracker such as the
30   pulse encoder described above is commonly present in most
existing moving line installations and is thus convenient to
use as the basis for a common reference value.

In more detail, a method of the invention includes that, as
35   well as the known or normal status and control signals between

the robots, and between the robots and the cell controller,
the following signals are interchanged according to an
embodiment of the invention:

-distribution of a common reference value; preferably a
5   position or movement indication relative the work object; or a
coordinated time signal;

-signals or functions for notifying a superior controller, eg
cell controller 31, about the present local execution position
or execution point so that the object and/or other robots can

10 be halted. The result of this inventive method is that each or
any robot may only stop at the completion of a task. To re-
start the cell or line after a normal interruption or
production stoppage, it is then only necessary to reset or
withdraw the wait signal and each robot then re-starts from a

15 known position in their Movement Program. The robots simply
proceed with the task that was to follow the last task that
the robot completed. Thus a line re-start may be carried out
automatically and without undue manual and specialist work and
time to re-coordinate robots relative to each other or the

20 work object, so that all properly functioning robots simply
resume work according to the program instructions in their
individual Movement Program 31.

Figure 5 shows a flowchart for a method of controlling one of
25 a plurality of robots according to a preferred embodiment of
the invention. It shows an operation to count or measure 41 a
distance travelled by a work object, and a comparison decision
42 to determine if the work object has stopped travelling.
Thus in this embodiment, the common reference value is based

30 on the relative movement, travel, of the work object. If the
work object stops moving, then the status of the reference
value is changed in the control program. In other words, if
Yes, 47, a software flag or program code flag is set to high.
The result of this is that when the robot concerned comes to

35 the end of the present task, it is then instructed to wait

(stop). A very short interruption of the line may result then
in that perhaps only one robot stops and waits for a short
time, and subsequently restarts as soon as the flag is
removed, while other robots perhaps continue their tasks with
5   being stopped or otherwise affected by a relatively short
stoppage of another robot.

If the result of reference value comparison 42 is No, then the
flag is not set high. In addition to a No at 42, another
10   operation may follow that, which is to check if there is an
existing flag is set high. If Yes, 49, then that flag is
lowered 45 or in a similar or an equivalent way, removed,
because the object is travelling. If No, 47, then the measure
or counted result for position of the work object is reported
15   48 and/or stored. Optionally, a report of the present status
(high or not high) for this flag may be stored and/or reported
to the cell controller.

The coordination can be carried out by letting the superior
20   controller such as cell controller 31 supervise so that all
robots always are within a individually configurable tolerance
window from the relative time and/or position recorded in
coordination teaching mode.

25   The coordination function can also run completely independent
from any superior controller. The comparisons may take place
locally in a robot controller for each of one or more robots
and then signals sent to the other robot(s), and/or a conveyor
controller, to halt when a work object or robot comes outside
30   its window limits. See for example descriptions below ref
Figure 8 about sub routines or programs 86, 87, 85, 85a
comprised to run in a robot controller 81.

Figure 6 shows a flowchart for continually checking the status
35   of a reference value, a reference value such as that the work

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object is or is not moving according to predetermined values.
It shows that a status check 61 is carried out to determine if
a flag relative the reference value is high. If the flag is
high, meaning that the work object has stopped travelling, the

5   Yes, 62, results in that the robot will wait 64 at the end of
the present task. If, in contrast the result of status check
61 is a No, 66, then this means that nothing happens, and the
robot continues operating without any changes due to check 61.
This status check is may be repeated almost continuously at a

10   suitable, predetermined sampling frequency. The status check
may also be performed at predetermined intervals such as just
before the beginning of a subsequent task for the first robot,
and/or just before the beginning of a subsequent task of
another robot of the working group.

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Figure 7 shows a similar flowchart to Figure 6. Figure 7 is a
flowchart for a method to check if any of the other robots
have stopped, that is, are waiting instead of proceeding to
the next task. Figure 7 shows that a status check 71 is

20   carried out to determine for any robot in the section or
production cell has a flag relative the reference value that
is set to high. If a flag for any robot in the section is
high, meaning either that the work object has stopped
travelling relative that section, or that the robot in

25   question is presently waiting 64 for any reason, then the
the Yes, 72, results in that the robot will wait 74 at the end
of the present task. As before for Figure 6, if the result of
status check 71 is a No, 76, then this means that nothing
happens, and the robot continues operating without any changes

30   due to check 71, which check is repeated at suitable
intervals. Again, this may be repeated before a first robot
starts the next task, before another robot starts a next task,
and/or before any or all of the robots start a subsequent
task.

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Figure 8 shows a schematic block diagram of a local robot
controller 81 with members, parts and software for monitoring
for the reference value (common reference, position reference,
robot waiting or common time reference etc) to control

5   operation of a robot such as robots 1-n of Figure 3. It shows
that the robot controller includes a hardware I/O interface
82, a processor or computer 83, a RAM memory 84, and
preferably non-volatile or even long term memory storage 89.
The robot controller also has one or more programs that run in

10   the controller processor 83, including a movement program 85.
Movement program 85 may comprise a program or routine 42 for
checking a value for the common reference 41 to see if it is
not acceptable, flag high 43. This program or routine may be
comprise in the movement program 85, or in a separate program

15   85a similar to programs 86, 87 below.

Figure 8 also shows a program or routine for checking 86 if a
flag for a robot controlled by the controller 81, eg a
position reference value for the robot, is high. Another

20   program or routine or sub-routine is also shown provided for
checking 87 if whether any other robot in the cell has a flag
set high.

The robot controller 81 issues instructions in the form of

25   signals to the robot, robot hardware I/O 813 via the
controller hardware I/O interface 82. Robot controller
hardware I/O 82 also receives sensor input, such as sensor I/O
812 and also a reference sensor 811, which may be a pulse
encoder on a conveyor, another position sensor for a work

30   object, a local clock or time signal, or other reference value
generator. Robot controller hardware I/O 82 also receives
input from the cell controller 31 and may send output to the
cell controller. The robot controller 81 may be a standard
off-the-shelf component such as a programmable controller, but

35   it has to be programmed with, or by another means made to run

software code portions or computer programs according to the
invention, and supplied as necessary with information in
respect of the reference value or reference value status.

5   Sensor input to sensor. I/O 812 may be provided by one or more
wireless sensors installed on or arranged in cooperation with
a robot. Similarly, the robot hardware I/O 813 may comprise a
wireless I/O to send and/or receive wireless signals.

10   The reference value status may also be generated from a cell-
specific or robot-specific target position instead of from a
more universal position indicator such as the line movement
pulse encoder for the conveyor. When each Movement Program 21
is put through the coordination teaching run in step 22, as
15   shown in Figure 2, before every stroke, a position of the
target is recorded and may be saved in an array. Thus, for the
beginning of every movement and therefore for every task,
there is an associated target position. During normal
operations the robot may check the target position stored in
20   array before the start of the task (movement), and compare it
to a measurement of what the present target position is now. A
decision can be made if that target position is within a
window around the predetermined, expected start position
saved, for example in an array. If the measured position is
25   outside the permissible window of the saved position, a
reference value status of not acceptable, equivalent to high
flag 43 of Figure 5, is established at that moment for that
robot. Thus, if the measured position is outside the window,
the reference status goes to not acceptable, flag high, and
30   the robot is instructed to wait, equivalent o 64 of Figure 6.
If the status is acceptable, no flag, then the next task is
proceeded with. The reference value statuses established for
each start position comparison in a production cell may be
sample continuously by the cell controller 31. Some or all

reference value statuses for each cell may be sampled by
another control system controlling other sections of the line.

5   Thus to summarise, if a work object is out of position, a
first robot waits before beginning the next task until the
work object is within the position window. After the work
object has moved into the position window as measured by
current position measurement, the reference value becomes re-
set, and the first robot proceeds with the subsequent task.

10   The movement program may later be fine tuned by teaching 22
one or more of the plurality of specific movements or tasks in
the movement program 21 to improve speed or quality.

Thus it may be understood from the above that the inventive

15   method also allows a robot to be intentionally paused, or
temporarily halted, until another robot has completed a given
task. This is a very advantageous feature. For example in a
painting operation, a "helper" robot may be programmed to
open a vehicle door at the right time and position so that a

20   second robot may reach inside the vehicle to paint the body
interior. The helper robot may be programmed so that it waits
until the second robot has finished painting the interior,
signalled in this example by that the second robot stops
painting, retracts from the vehicle interior, and begins a

25   wait state. When the helper robot obtains information that the
second robot is waiting by means of that the reference value
for that event shows a high flag for the second robot, it
closes the vehicle door, retracts, and then begins a wait
state of its own prior till the time when the next vehicle

30   reaches the expected target position.

In another embodiment of the invention one or more robots are
equipped with wireless communication between a robot control
function and a component of the robot, or a sensor arranged to

35   cooperate with a robot, or both. The use of wireless

communication for selected monitoring and control functions is
particularly advantageous, for example, for applications where
automatic tool changes may be carried out by the robot,
preferably so that no operator intervention is required in the
5   production cell area.

In another, less preferred embodiment, a reference value may
comprise a value for percentage of completion of a job. A
measure of relative completion of a job may be used as a basis
10   to provide a common reference value. This may be selected in
situations where work objects are not transferred to and form
the production cell by a conveyor or other moving line. In
this case the reference value is generated by change or
increment in a relative completion counter. Upon a change
15   outside of a predetermined window in the value of the relative
completion or percentage completion value being signaled, then
at least one of the robots will set a flag high, as described
above.

20   The methods of the invention may, as previously described, be
carried out by means of one or more computer programs
comprising computer program code or software portions running
on a computer or a processor. The microprocessor (or
processors) comprises a central processing unit CPU performing
25   the steps of the method according to one or more facets of the
invention. This is performed with the aid of one or more said
computer programs, such as 85, 85a, 86, 87, which are stored
at least in part in memory such as 84, 89 accessible by the
one or more processors. The or each processor may be in a
30   central object oriented control system in a local or
distributed computerised control system. It is to be
understood that said computer programs may also be run on one
or more general purpose industrial microprocessors or
computers instead of one or more specially adapted computers
35   or processors.

The computer program comprises computer program code elements
or software code portions that make the computer perform the
method using equations, algorithms, data, stored values and

5   calculations previously described. A part of the program may
be stored in a processor as above, but also in a ROM, RAM,
PROM, EPROM or EEPROM chip or similar memory means. The
program in part or in whole may also be stored on, or in,
other suitable computer readable medium such as a magnetic

10   disk, CD-ROM or DVD disk, hard disk, magneto-optical memory
storage means, in volatile memory, in flash memory, as
firmware, stored on a data server or on one or more arrays of
data servers. Other known and suitable media, including
removable memory media such as Sony memory stick (TM) and

15   other removable flash memories, hard drives etc. may also be
used.

The computer programs described may also be arranged in part
as a distributed application capable of running on several

20   different computers or computer systems at more or less the
same time. Programs as well as data such as start positions,
or flag-related information may be made available for
retrieval, delivery or, in the case of programs, execution
over the Internet. Data may be accessed by means of any of:

25   OPC, OPC servers, an Object Request Broker such as COM, DCOM
or CORBA, a web service. Methods of the invention may also be
practised, for example during a teaching or configuration
phase, during operations, off-line or following a stoppage, by
means of a Graphical User Interface (GUI), a graphical or

30   textual display on an operator workstation, running on a
user's logged-in computer, which may be connected direct to
the robot control system or connected via a main or local
control server or other control system computer.

21

Wireless communications may be carried out using any suitable
protocol or standard. Short range radio communication is the
preferred technology, using a protocol compatible with: a
standard issued by the Bluetooth Special Interest Group (SIG),
5   any variation of IEEE-802.11, WiFi, Ultra Wide Band (UWB),
ZigBee or IEEE-802.15.4, IEEE-802.13 or equivalent, or
similar. Wireless communication may also be carried out using
Infra Red (IR) means and protocols such as IrDA, IrCOMM or
similar; similarly sound or ultrasound transducers, through
10 the air or via the robot construction, or may be used.

It is also noted that while the above describes exemplifying
embodiments of the invention, there are several variations and
modifications which may be made to the disclosed solution
15 without departing from the scope of the present invention as
defined in the appended claims.